Evaluation of the Extent of the Non-Native Insect, Balsam Woolly Adelgid, South of the Salmon River in Idaho from 2006-2014 by Ground Delimitation and Aerial Detection Surveys

BFO-PR-2015-01

Introduction

Balsam woolly adelgid (BWA), *Adelges piceae* (Ratz.) (Hemiptera: Adelgidae), a non-native, invasive, piercing/sucking insect, was introduced to North America from Europe around 1900. Infestations were discovered on the west coast in California during the 1930s and in Oregon and Washington in the 1950s and 1960s (Mitchell et al. 1970). It is has caused subalpine fir (SAF) mortality and impacted grand fir (GF) growth and vigor in Idaho since its discovery in 1983 (Livingston et al. 2000). Infestations can cause long-term tree decline, deformity, growth reduction, or death in as little as three years. Infested trees stressed by BWA are often killed by other insect and disease pests (Mitchell and Buffam 2001).

One BWA female can lay 200+ eggs, which are all female. Depending on elevation, BWA can have two (high elevations) to four generations (low elevation drainage bottoms) per year. Damage is correlated positively to number of generations. This pest distributes passively, mainly carried by wind, animals, and humans to new locations during its mobile "crawler" stage. Adult females secrete waxy, wool-like strands over their bodies, protecting the adult and its eggs. This wool is found on branch undersides and the main stem of trees. BWA damage its hosts by injecting toxic saliva. The host's reactions include gout (swelling of wood tissues near branch nodes) and deformation/ thickening of vascular tissues, and production of a type of compression wood. This reaction interferes with the transport of water and nutrients within the tree, often leading to needle chlorosis, premature needle loss and crown dieback.

Prior to 2000, the range of BWA in the western US was thought to be limited to Washington, Oregon and select areas of northern Idaho, north of the Salmon River (Livingston et al. 2000, Overhulser et al. 2004, Ragenovitch and Mitchell 2006). In 2001, BWA was found infesting a few trees south of the Salmon River in McCall, Idaho on private lands, but not on US Forest Service (USFS) managed lands. These infested trees were treated chemically through consultation with Idaho Department of Lands (IDL). No other actions were taken until 2005 when Forest Health Protection (FHP) and IDL visited impacted trees in and around McCall and found trees showing signs of severe gouting, stem infestations and mortality.

Detection of BWA in other areas of the Northwest has been through both ground and aerial surveys. Aerial Detection Surveys (ADS) have routinely recorded BWA impacts in Oregon and Washington based on a black lichen signature (Mitchell and Ragenovich 2006). ADS began recording acres impacted by BWA in 1984 in northern Idaho. However, the aerial signature in Idaho was based on a unique red color found on dead and dying trees and internal needle fade of the crown, because the black lichen association is very weak in the drier Idaho forest types. Since no BWA was found in 1990s ground surveys in southern Idaho, SAF mortality observed through ADS was recorded only as SAF decline complex south of the Salmon River. Limitations of ADS detections are that they do not adequately capture the extent of

current BWA infestations, as infestations can occur years before a signature is detected by aerial observers conducting ADS. Ground surveys by Gast et al. (1990) and Livingston et al. (2000) have estimated millions more impacted acres than what aerial surveys could detect. As a result of the McCall infestation and to augment BWA range information provided by ADS, a collaborative ground survey effort was planned to re-examine areas surveyed in northern Idaho by Livingston et al. (2000) and expand into additional true fir landscapes with road access. Project collaborators included FHP personnel (Entomologists Lee Pederson (Region 1), Laura Lowrey (Region 4), Biological Technician Chad Nelson (Region 4)), and IDL personnel (former Forest Health Program Manager Jeff Fidgen, former Invasive Species Coordinator Neal Kittelson, and former Biological Technicians David Beckman, and Brian Burkhead). This report documents only the findings from the Region 4 survey portion of BWA dispersal into new areas of true fir landscapes.

Methods

A series of georeferenced, roadside plots (Fig. 1) were established in 2006 and 2007 in areas known to have SAF or GF. Sampling continued along the road until the type or the road ended. Travel, budgets and time constraints dictated how many areas were surveyed each year. Where SAF had a discontinuous distribution, the area was checked for true fir and BWA at 1-mi. intervals. Plots were established at 2-mi. intervals in large, contiguous stands of true fir. At each plot, a presence-absence survey was conducted for BWA by examining true fir at eye-level. A plot was considered infested if one BWA was found, and un-infested if no BWA were found after 10-min of searching true fir. Stem infestations were rated low (1 woolly adult/square foot), moderate (2-25 woolly adults/square foot), and high (>25 woolly adults/square foot). In the absence of BWA, a plot was also considered infested if gouting was detected on any true fir twigs or branches. Other variables recorded at each site were slope, aspect, elevation. SAS Enterprise Guide was used to fit a multiple logistic model using the variables of aspect, slope, latitude, longitude and elevation.

In 2006 ground surveying was completed on the Payette NF and surrounding ownerships expanding outward from McCall. In 2007 other areas were surveyed to delimit the range boundary, such as the Boise, Sawtooth and Salmon-Challis National Forests. No range boundaries were delimited in 2006-2007, so surveys continued through 2010 in Idaho when possible to estimate range boundaries. One positive detection was sufficient to include a county in the new range for BWA.

Results and Discussion

Extent. Between the 1997-1998 and 2006-2007 surveys, the range of BWA advanced over 100 miles south and southeast into Idaho (Figure 1). BWA was commonly found on the Payette NF at various levels. Further surveys through 2010 found the range expansion to be even more extensive, nearly 300 miles east, to bordering Montana and Wyoming (Figure 1). Various levels of BWA infestations were found during the surveys and can be expected throughout the “new range” of BWA (Figure 2). No BWA was found in the Owyhee Mountains or southeastern Idaho bordering Utah. Utah, Wyoming, and Nevada were not officially surveyed.

Figure 1. The spread of BWA across true fir of all land ownerships in Idaho from 1997 to 2010. Areas highlighted in different colors depict land surveyed during the same timeframe. Various levels of BWA infestations-from high to none- can be found thoughout these areas.

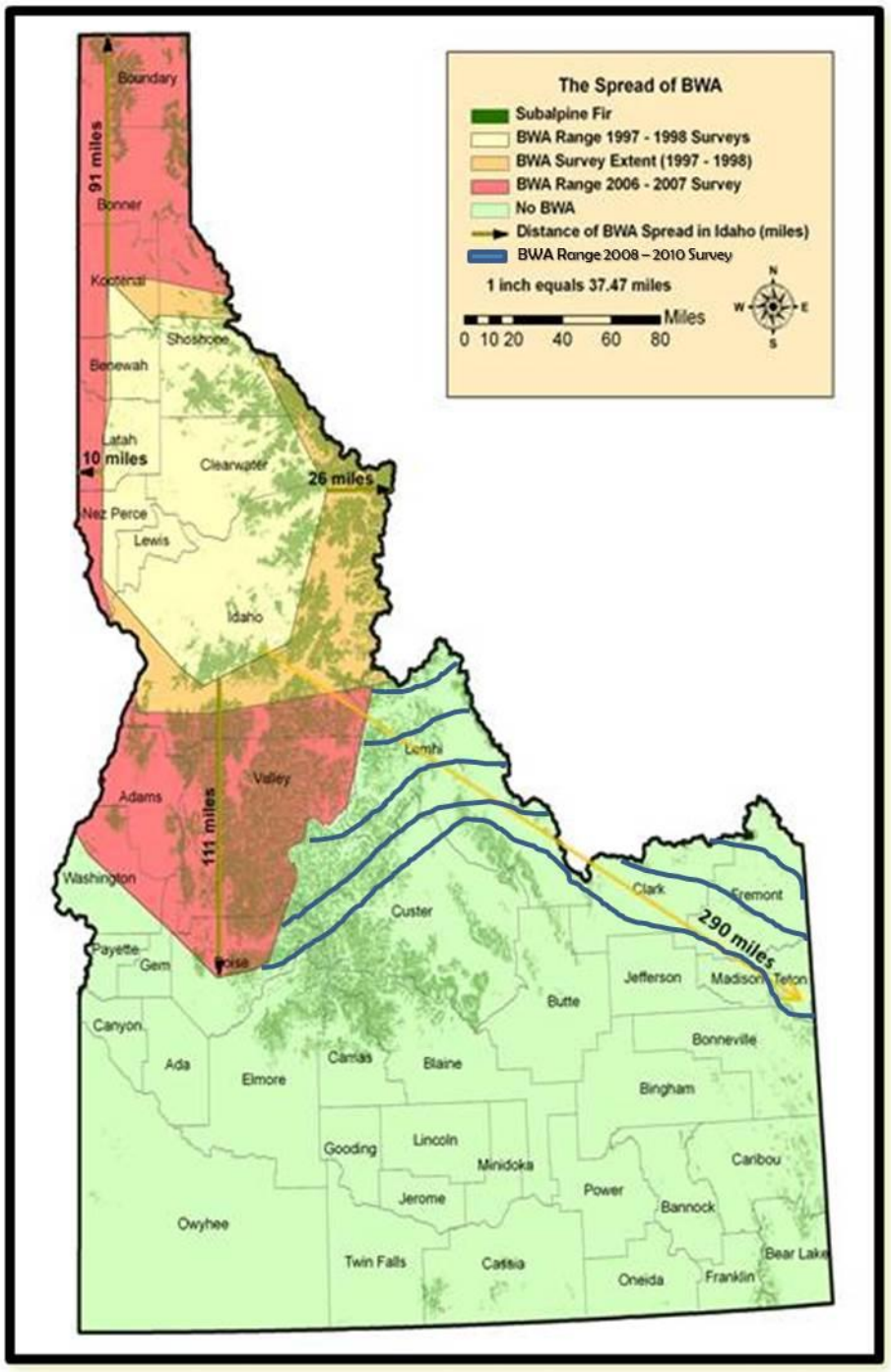
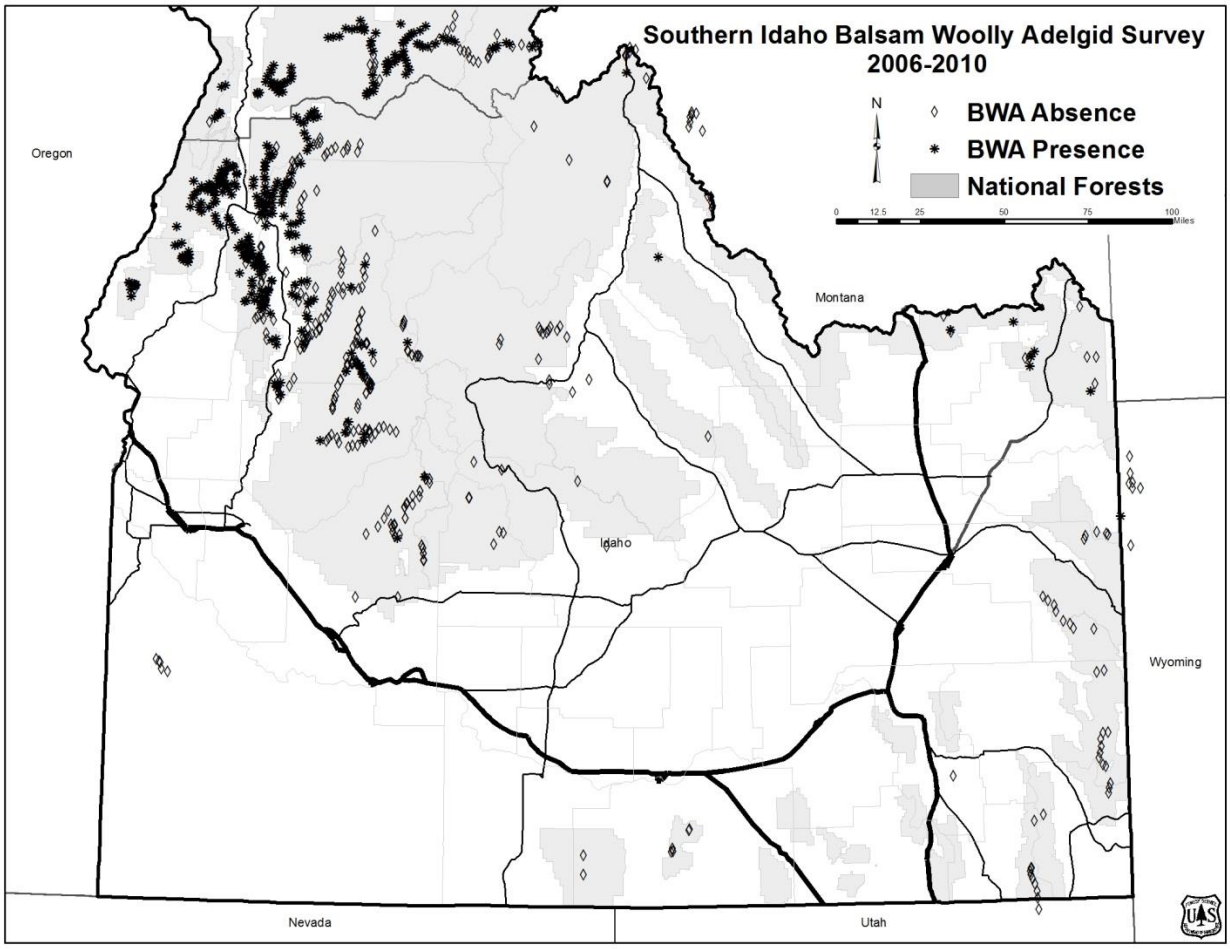


Figure 2. Ground survey locations, 2006-2010, of BWA across true fir of all land ownerships. Solid dots (asterisks) signify presence at ground survey locations.



A total of 1,287 spots were surveyed from 2006 to 2010 with 49% of them positive for BWA presence (Figure 2). Overall, levels of BWA infestation levels varied at new locations. It is likely that BWA has been in some of these areas for nearly 20 years (southwestern Idaho, except Owyhees) and some were invaded much more recently. BWA infestations were found from 1,876 to 7,913 ft. There was a statistically significant difference between the mean elevations for BWA absence, 5,876 ± 28 ft., and presence, 4,755 ± 16 ft., ($p<0.0001$, SAS GLM). High densities of BWA were found up to 6,932 ft. and moderate densities to 7,145 ft. Gouting was found at 15 % of survey locations.

Logistic regression was used to fit the binomial response of BWA presence/absence on the set of potential predictors, including slope, aspect, elevation, latitude and longitude. Elevation in meters was divided by 100 for ease of parameter interpretation. Model fitting was done using SAS/STAT Software ® version 9.4 (SAS Institute, Inc., 2014) of the SAS System for Windows. Slope and aspect were not significant when the full model was fit ($p=0.94$ and $p=0.21$ respectively) and were removed from final model. The three remaining predictors were significant ($p < 0.0001$). The final model Area Under Curve (AUC) was 0.79 indicating the estimated probability that the model will predict a randomly chosen BWA occurrence to have a higher predicted probability than a randomly chosen BWA non-occurrence is 0.79.

Interpretation of odds ratios reported in Table 1 indicate the following:

a) for each 100m increase in elevation, odds of being present decreases by (1-0.781) or 21.9%,
b) for each degree increase in latitude, odds of being present decreases by (1-0.709) or 29.1%, and
c) for each degree increase in longitude, odds of being present decreases by (1-0.451) or 54.9%.

Table 1. Odds ratio estimates and 95% confidence limits showing odds of correctly predicting presence of Balsam woolly adelgid in southern Idaho.

Effect	Point Estimate	95% Wald Confidence Limits	
DEM_Elv_100m	0.781	0.753	0.810
LAT	0.709	0.642	0.782
LONG	0.451	0.385	0.530

Statistical analyses were conducted by David Turner, Retired Regional Statistician and L. Scott Baggett, Statistician, Rocky Mountain Research Station. Further analyses of the entire dataset for the state of Idaho from 2006-2008 and beyond will occur in the near future in cooperation with FHP Region 1 and Idaho Department of Lands.

Aerial Detection Survey Changes.

Based on the extent and severity of BWA found from 2006-2010, ADS observers began recording the signature used in Idaho in 2011. Since implementation of this signature in southern Idaho, 32,155 acres have been recorded by ADS (Figure 3). This is a factor of both increasing familiarity of the damage signature and increasing impacts from BWA. In both 2013 and 2014, ADS detected BWA impacts beyond our "working" range as depicted in Figure 1. The 2006-2010 ground survey omitted many areas because of time constraints inherent with conducting a roadside survey. ADS will be important for picking up new infestations in remote areas in the future, however, they should be followed up by site visits on the ground for confirmation. Ground observations indicate that mortality of SAF and other damages to true fir are increasing throughout the range.

Future BWA Expansion.

Winter temperature is likely a very important factor determining the future distribution of BWA. Quiring et al. (2008) found that a mean January temperature of 12° F (-11° C) explained presence or absence of BWA in New Brunswick. We do not know if the survival threshold found by Quiring et al. (2008) holds true in the US Rockies, but so far it seems to be the same in lower latitudes. Mean January temperatures between 1971 and 2000 were overlaid with the detection data from 2006-2010 to demonstrate what warming temperatures could mean for future range expansion (Figure 4). The presence of BWA matches up very well with the temperature survival threshold. Temperature data layers for 2001-2011 were not yet available, but those years included winters warmer than the previous decade and could provide an

opportunity for BWA establishment at higher elevations. As more areas become conducive for BWA we expect continual spread East, North and South of known locations. It seems BWA could survive in much of the Intermountain Region (western Wyoming, Utah and Nevada).

BWA establishment into new areas of true fir will have varied impacts because of many factors that we do not yet fully understand. However, anticipated temperatures can help predict BWA impacts. If Quiring et al.'s winter temperature thresholds hold true, some areas will remain too cold for BWA establishment. For some infested areas mortality impacts may be slow and minimal because sporadic, cold winter temperatures should reduce BWA populations. For example, mortality of SAF has increased in warmer and lower elevations and is now widespread in moderate sites since the first ground detections were made on the Boise National Forest (personal observations, Figure 3).

Figure 3. Areas in southern Idaho impacted by BWA and detected by Aerial Detection Survey between 2011-2014 (Wilderness areas were not surveyed).

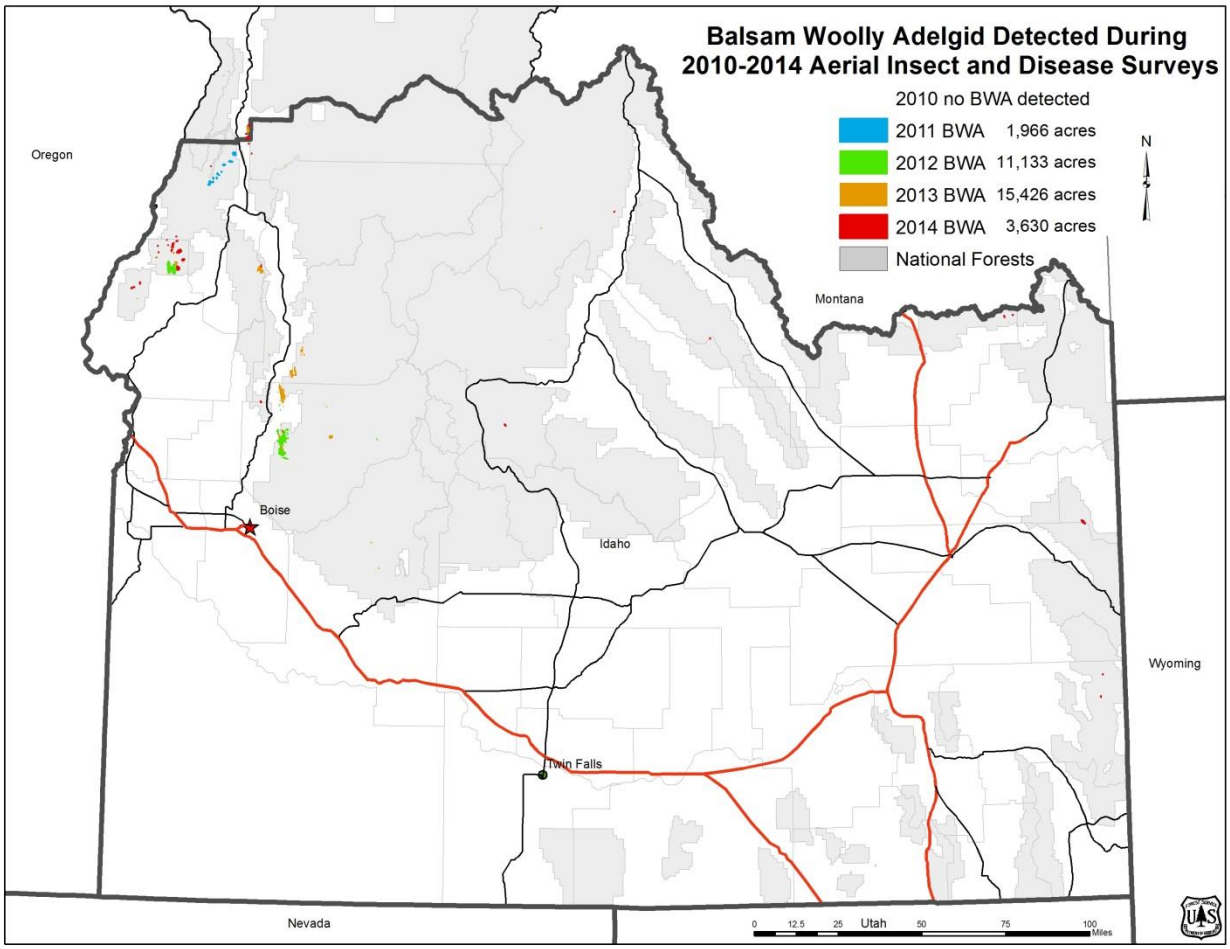
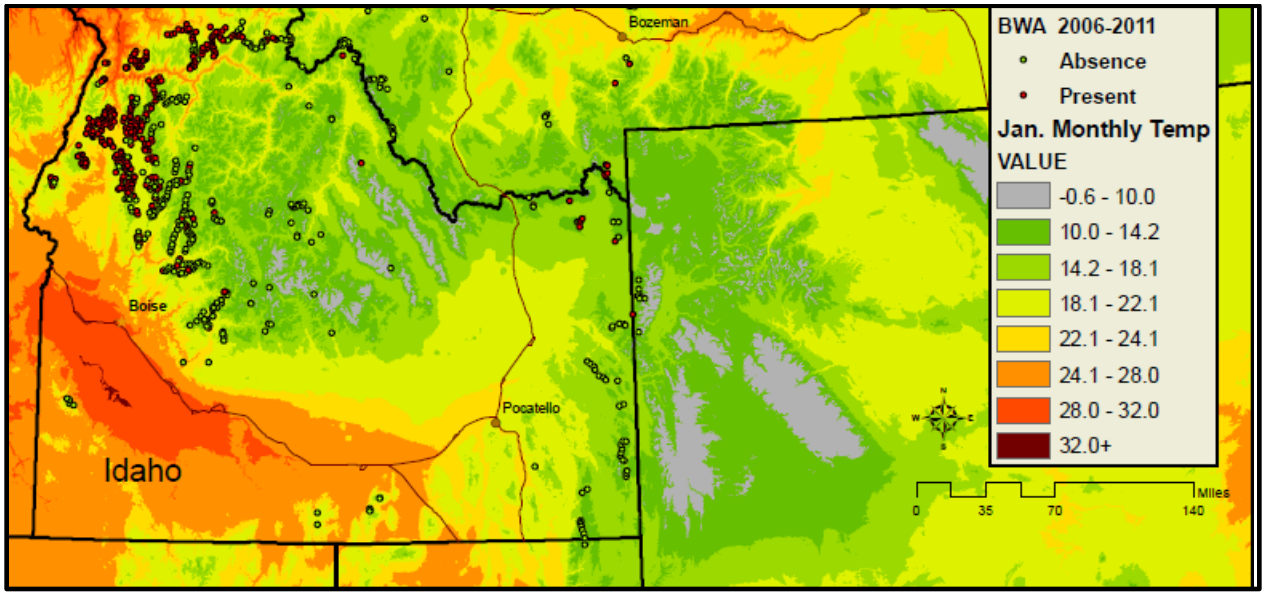


Figure 4. Mean January temperatures (Fahrenheit) (1971-2000), NOAA sites and the locations surveyed for BWA across all land ownerships from 2006-2011.



Expanding infestations may result in significant losses of SAF and adversely affect ecosystem and land management resources. Hydrological effects could include: reduced groundwater retention, increased rate of snow melt, and altered stream flow characteristics and stream temperatures (Kenis et al. 2009, Gandhi and Herms 2010, Evans et al. 2011). Fire danger and behavior could be impacted because of increased fuel loading from dead trees (Lyon et al. 1976, Bentz et al. 2010). Wildlife may be affected by changes in stand composition (Saunders 1955, Houston 1968, Ritchie 1978, Contreras et al. 1986, Scott et al. 1982, Schroeder 1984). Continued monitoring through aerial detection and ground surveys will aid in impact predictions and any considerations for mitigation management. The passively spreading nature of BWA combined with warmer temperatures makes range expansion of BWA very likely for all true fir stands in the US Rockies in the coming decades (Lass et al. 2014). Continued surveys and studies to document this major change to US Forests are needed so land managers can make informed decisions on this Nation's natural resources.

If you have any questions or comments regarding this report, or if you require any further information on the biology and/or management of forest insects/diseases, please contact me by phone at 208.373.4226, or email at laurallowrey@fs.fed.us.

/s/ *Laura L. Lowrey*

Laura L. Lowrey
Entomologist
Intermountain Region
Forest Health Protection

Literature Cited

Bentz, B., J. Régnière, C.J. Fettig, E.M. Hansen, J.L. Hayes, J.A. Hicke, R.G. Kelsey, J.F. Negrón, and S.J. Seybold. 2010. Climate change and bark beetles of the Western United States and Canada: Direct and indirect effects. Bioscience 60: 602-613.

Contreras, G.P., and K.E. Evans, compilers. 1986. Proceedings-grizzly bear habitat symposium. General Technical Report. INT-207. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 252 p.

Evans, D., M. Aust, C. Dolloff, B. Templeton, and J. Peterson. 2011. Eastern hemlock decline in riparian areas from Maine to Alabama. Northern Journal of Applied Forestry 28(2): 97-104.

Gandhi, J.K.J., and D.A. Herms. 2010. Direct and indirect effects of alien insect herbivores on ecological processes and interactions in forests of eastern North America. Biological Invasions 12: 389-405.

Gast, S., D.P. Beckman, R.L. Livingston, and J. Gustin. 1990. Distribution of the Balsam Woolly Adelgid in Idaho. USDA Forest Service Report 90-5. Northern Region. Missoula Montana. 1-8.

Livingston, R.L., J.E. Dewey, D.P. Beckman, and L.E. Stipe. 2000. Distribution of the balsam woolly adelgid in Idaho. Western Journal of Applied Forestry 15: 227 – 231.

Houston, D.B. 1968. The Shiras Moose in Jackson Hole, Wyoming. Tech. Bull. No. 1. [Place of publication unknown]: The Grand Teton Natural History Association. 110 p.

Kenis, M. , M. Auger-Rosenburg, A. Roques, L. Timms, C. Pere, M. Cock, J. Settele, S. Augustin, C. Lopez-Vaamonde. 2009. Ecological effects of invasive alien insects. pp. 21-45 *In* Ecological Impacts of Non-Native Invertebrates and Fungi on Terrestrial Ecosystems.

Lass, L.W., S.P. Cook, B. Shafii, and T.S. Prather. Development of a dispersal model for Balsam woolly adelgid, *Adelges piceae* Ratzeburg (Hemiptera: Adelgidae), to facilitate landscape-level management planning. International Journal of Forestry Research: p. 1-8.

Lyon, L.J., and P.F. Stickney. 1976. Early vegetal succession following large northern Rocky Mountain wildfires. In: Proceedings, Tall Timbers fire ecology conference and Intermountain Fire Research Council fire and land management symposium; 1974 October 8-10; Missoula, MT. No. 14. Tallahassee, FL: Tall Timbers Research Station: 355-373.

Mitchell, R.G., and P.E. Buffam. 2001. Patterns of long-term balsam woolly adelgid infestations and effects in Oregon and Washington. Western Journal of Applied Forestry 16: 121-126.

Mitchell, R., N.E. Johnson, and J.A Rudinsky. 1961. Seasonal history of the Balsam woolly adelgid in the Pacific Northwest. The Canadian Entomologist: 794-798.

Mitchell, R. G., G.D. Amman, and W.E. Waters. 1970. Balsam woolly aphid. Pest Leaflet 118. USDA Forest Service, Washington, DC. 9p.

Overhulser, D.L., I.R. Ragenovich, M. McWilliams, and E.A. Willhite. 2004. Balsam woolly adelgid occurrence on true fir in Oregon. Oregon Department of Forestry Pest Management Report. 7 p.

Quiring, D., D. Ostaff, L. Hartling, D. Lavigne, K. Moore, and I. DeMerchant. 2008. Temperature and plant hardiness zone influence distribution of balsam woolly adelgid damage in Atlantic Canada. The Forestry Chronicle. 84: 558-562.

Ragenovich, I.R., and R.G. Mitchell. 2006. Balsam woolly adelgid. Forest Insect and Disease Leaflet 118. USDA For. Serv., Washington, DC. 11 p.

Ritchie, B.W. 1978. Ecology of moose in Fremont County, Idaho. Wildlife Bulletin No. 7. Boise, ID: Idaho Department of Fish and Game. 33 p.

Saunders, Jack K., Jr. 1955. Food habits and range use of the Rocky Mountain goat in the Crazy Mountains, Montana. Journal of Wildlife Management 19(4): 429-437.

Schroeder, R.L. 1984. Habitat suitability index models: Blue grouse. FWS/OBS-82/10.81. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service. 19 p.

Scott, V.E., G.L. Crouch, and J.A. Whelan. 1982. Responses of birds and small mammals to clearcutting in a subalpine forest in central Colorado. Res. Note RM-422. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 p.

SAS Institute Inc. (2014) SAS/STAT® 13.2 User's Guide. Cary, NC: SAS Institute Inc.